



GB 00/04403



INVESTOR IN PEOPLE

BEST AVAILABLE COPY

**PRIORITY
DOCUMENT**SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH RULE 17.1(a) OR (b)The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ#3
47154P01
R. Talbot

REC'D 28 DEC 2000

WIPO

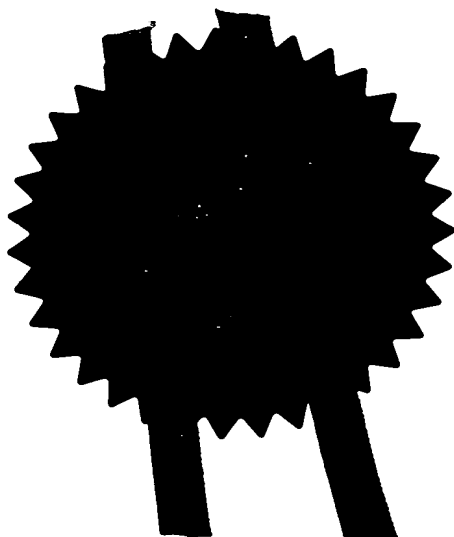
PCT

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.



Signed

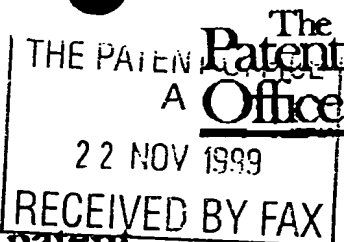
Dated

18 DEC 2000

THIS PAGE BLANK (USPTO)

Form 1/77

Patents Act 1977
(Rule 16)



Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference
454GB
22NOV99 E493487-1 D02651
FOI/7700 0.00-9927471.4
2. Patent application number
(The Patent Office will fill in this part)
9927471.4
22 NOV 1999
3. Full name, address and postcode of the or of each applicant (underline all surnames)
Renishaw plc
New Mills
Wotton-under-Edge
Gloucestershire
GL12 8JR
2691002
Patents ADP number (if you know it)
If the applicant is a corporate body, give the country/state of its incorporation
United Kingdom
4. Title of the invention
Position Determining Apparatus
For Coordinate Positioning Machine
5. Name of your agent (if you have one)
J Waite et al
"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)
Renishaw plc, Patent Department
New Mills
Wotton-under-Edge
Gloucestershire
GL12 8JR
Patents ADP number (if you know it)
2600005
6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country	Priority application number (if you know it)	Date of filing (day / month / year)
-	-	-
7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing (day / month / year)
-	-
8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))
Yes

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form

Description

Claim(s)

Abstract

Drawing(s)

11/

0

0

4

RECEIVED BY FAX

10. If you are also filing any of the following, state how many against each item.

Priority documents 0

Translations of priority documents 0

Statement of inventorship and right to grant of a patent (Patents Form 7/77) 0

Request for preliminary examination and search (Patents Form 9/77) 0

Request for substantive examination (Patents Form 10/77) 0

Any other documents (please specify) 0

11.

I/We request the grant of a patent on the basis of this application.

Signature

Date 22.11.1999

AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom

AILES 01453 524524

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

- If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.
- Write your answers in capital letters using black ink or you may type them.
- If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.
- If you have answered 'Yes' Patents Form 7/77 will need to be filed.
- Once you have filled in the form you must remember to sign and date it.
- For details of the fee and ways to pay please contact the Patent Office.

1

POSITION DETERMINING APPARATUS FOR COORDINATE POSITIONING MACHINE

The present invention relates to an apparatus which
5 enables a coordinate positioning machine (such as a machine tool) to determine the position of an object relative to a reference point. It may, for example, be employed on a machine tool for toolsetting operations.

- 10 A known tool setting device for use on a machine tool includes a light source which generates a fine beam of light which is incident upon a detector. During a toolsetting operation, the machine is operated to move the tool in a direction transverse to the direction of
15 propagation of the light beam until a part of the tool interrupts passage of the light beam. Detection of this interruption results in the generation of a trigger ~~signal in the detecting unit, which is used by the~~
machine to establish the relative position of its moving
20 parts in order to determine dimensions of the tool. Such devices are known, for example, from German Patent Nos. DE 42 385 04 and DE 42 448 69, French Patent No. 2,343,555, European Patent No. 98,930 and US Patent No. 4,518,257. The devices may be used additionally for
25 measuring the length or diameter of a tool to monitor tool breakage or wear.

The devices disclosed in the above-mentioned patent specifications use a narrow light beam into or through
30 which the tool is passed. The detection units detect when the tool breaks into the beam from the resulting drop in the intensity of the light falling on them.

The accuracy with which these devices can measure tool

2

position is dependent on the diameter of the laser beam, the smaller the diameter the more accurate the measurement.

5 For example, French Patent No. 2,343,555 describes a system in which the laser produces a coherent beam the diameter of which is of the order of 0.7 to 0.8mm. European Patent No. 98,930 proposes the use of a laser light source because lasers supply a sharply focused
10 light beam for high measurement accuracy. US Patent No. 4,518,257 describes a system in which the laser beam is focused to a small examination zone at which all measurements are made.

15 A problem with a focused system, as in US Patent No. 4,518,257, is that the tool can only be measured in the small examination zone. Unfocused systems do not suffer
~~from this problem, but the beam must be accurately~~
aligned with an axis of travel of the machine tool to
20 permit accurate measurements anywhere along the beam path.

The present invention provides alternative devices which are suitable for toolsetting on a machine tool (or other
25 applications on other coordinate positioning machines). The devices include a number of technical aspects in which they differ from the prior art devices discussed above and which enable various ones of the problems which arise with those prior art devices to be eliminated or
30 reduced.

According to a first aspect of the present invention a device which enables determination of position of an object on a coordinate positioning machine includes a

3

light emitting unit and a detecting unit, the light emitting unit having a housing within which the light source is situated, the housing having a relatively small aperture through which light from the light source

5 passes, and which propagates towards the light detecting unit which in turn includes a housing having a relatively small aperture located in register with the light beam, and a light detecting device located substantially in register with the aperture thereby to detect the light
10 beam propagating from the light emitting unit, wherein the light beam is uncollimated and the detecting unit is arranged to emit a trigger signal when the light level it receives has fallen to one half of that which it receives when the beam is not occluded.

15

The term "small" in this specification is to be understood to mean preferably of the order of 1mm or less. The smallest aperture envisaged is of the order of
50 microns.

20

Embodiments of the invention will now be described, by way of example, and with reference to the accompanying drawings, in which:

Fig 1 is a perspective view of a first embodiment of
25 the present invention;

Fig 2 is a schematic illustration of aspects of the embodiment of Fig 1;

Fig 3 is a block diagram of part of the electronic circuitry of the detecting unit of Figs 1 and 2;

30 Figs 4a, 4b and 4c are diagrams showing steps in the set-up procedure;

Fig 5 is a flow diagram illustrating the switch-on routines;

Fig 6 is an illustration of the noise on the output

of the detector, and

Fig 7 is a circuit diagram for a further embodiment of the invention.

5 Referring now to Fig 1, a toolsetting apparatus which is suitable for use on, for example, a machine tool includes a light emitting unit 10 which emits a beam 12 of light, and a light detecting unit 14, where the light beam 12 is detected. Power and signal control cables to the light
10 emitting and detecting units 10,14 are routed via inlet ports 16, and both the units 10,14 are advantageously mounted, via pillars 18, on the base of the machine, either via an intermediate base 20, to which they are both mounted, or directly to the base of the machine upon
15 which they are to be employed.

In operation, the device is used for toolsetting by operating the machine on which the device is mounted to move the tool in a direction transverse to the direction
20 in which the beam 12 is propagating. When a predetermined level of occlusion of the beam has been established, the detecting unit 14 emits a trigger signal which is used by the machine to determine the relative position of its relatively movable parts, thereby to
25 enable dimensions of the tool to be determined.

Referring now additionally to Fig 2, the light emitting unit 10 comprises a laser diode 30 which generates a wide angle beam 12. The beam 12 passes first through an
30 aperture provided in a screen 32 to ensure that output power does not exceed safety levels. Subsequently the beam passes through a lens 33 and then through an angled pinhole aperture 34 in the housing of the unit 10. The lens reduces the divergence of the beam 12 but the beam

5

is deliberately not collimated and continues to diverge.

The casing of the light detecting unit 14 likewise includes an angled aperture 41 in register with which is a pinhole aperture 42 formed in a screen 43 and a translucent window 44 ahead of a photodiode detector 40.

By the time the beam 12 has propagated from the light emitting unit 10, and is incident upon the window 44, the spot created by its incidence is substantially larger than the aperture within the screen 42. Typically, over a distance of one metre between the light emitting unit 10 and the light detecting unit 14, the beam diameter will be of the order of 4mm, whereas the aperture within the screen 42 will be of the order of 200 microns.

Referring now to Fig 3, the output of the photodetecting diode 40 is passed to a variable gain amplifier 50 the output of which drives a display of five bar code LEDs 48 (see Fig 1).

The threshold level of the detector is set by a threshold detector 52 to provide a trigger signal when the intensity of the light falling on it drops to fifty percent of the unobstructed light level. This and the use of the pinhole at the emitter and detector units has the advantage that tool measurements can be taken anywhere along the beam even though the beam expands.

The maximum and threshold intensity levels are obtained during a set-up routine as follows:

When the laser is switched on its output rises to a maximum level at which it is stabilised by a high speed

6

control system. The laser beam is then aligned with the detector unit, and the bar code LED display provides an indication as to when proper alignment is achieved as described below with reference to Figs 4a, 4b and 4c.

5

The bar code LEDs are preferably tri-colour LEDs which are arranged, for example, to register all red at low amplifier output and all green when the amplifier output is maximum.

10

The gain of the amplifier is set to maximum. As the light falling on the photodiode 40 increases as shown in Fig 4a, its amplified output increases linearly, sequentially illuminating the bar code LEDs. When the amplifier voltage exceeds ninety-five percent of its maximum range, and all of the green LEDs are lit, the gain of the amplifier is reduced (see Fig 4b). This reduces the number of green LEDs that are illuminated

15

(see Fig 4c), and allows the amplifier to receive a greater signal level. As the alignment process continues and all of the green LEDs are lit again, this time at a higher maximum signal, the gain is once again reduced. The process continues reaching higher and higher signal maxima until proper alignment is achieved.

20

25

Once the correct alignment has been achieved and thus the maximum light level established, the light level is measured a plurality of times and the measurements averaged to provide a repeatable level. The dark level, i.e. the output of the detector when no laser light is incident upon it is also measured in order to set the fifty percent threshold level required for the trigger signal. Using the fifty percent level as the trigger threshold ensures an accurate and repeatable trigger

30

7

position regardless of the direction from which the tool enters the beam.

Because the accuracy of the trigger signal depends on the accuracy with which the fifty percent light level is measured, if the beam is blocked when the device is switched on, it automatically defaults into set up mode. Otherwise, if the beam is not blocked when the device is switched on, the routine for measuring the maximum light levels and the dark level is enabled so that an accurate 50% level is established each time the device is switched on. Fig 5 illustrates this routine.

If desired, the maximum light level and the dark level can be updated at intervals so that the fifty percent trigger level can be continuously updated.

Although the laser is driven at a constant light level, the intensity of light reaching the detector is variable for a variety of reasons, for example, relative movement between the screen 42 and the detector 40, atmospheric variations, or laser mode hopping. Thus the amplifier is provided with automatic gain control 54 to ensure that the resulting output provides the maximum signal to noise ratio.

It is also possible that the intensity of the light beam varies across its width and a further advantage of using the 200 μ m pinholes is that any variation in the intensity of light falling on the detector due to this cause is confined to the variation across the centre 200 μ m of the beam.

Further refinements may be added to the electronics. For

example coolant droplets could cause reductions of intensity in addition to that produced by obscuration of the beam due to the tool, and thus and give a false trigger signal. Since signal spikes due to this cause
5 are of short duration, the electronic circuit may include a timer which is re-set at the leading edge of each signal and if the signal is still there after a pre-set interval, for example, 5 milliseconds, it is assumed to be a genuine signal.

10

Also noise on the output of the photodiode could give rise to early triggering as the tool enters the beam as explained below.

15 Referring to Fig 6 it can be seen that if a noise spike reduces the apparent intensity adjacent the threshold level by an amount A , this gives rise to an error (e) in trigger position. Errors due to this cause can be

20 eliminated if the noise intensity bandwidth is monitored, and a value of half of the bandwidth is applied to output signal to lower the threshold level. A similar problem arises if the increasing intensity as the tool leaves the beam is used to obtain a second trigger signal, and a similar solution is applied to avoid this error.

25

Further, since the LEDs of the bar code array consume significant power, and thus heat up the detector array and cause errors, the electronic circuit may include a timer 56 which is arranged to pulse the power to the LEDs
30 at a pre-selected mark-space ratio, so that they are switched on and off sufficiently rapidly to give good visibility with no flicker whilst ensuring that they are switched off for a significant part of the time.

Finally a high speed tool breakage detection system has been included.

When a tool is being replaced in its tool holder it is
5 passed through the beam. The machine controller often
does not have the ability to constantly monitor all of
the inputs it receives. The electronic circuit of the
tool setter therefore includes a latch mode which is
selected for tool breakage monitoring. In this mode the
10 trigger signal produced by the tool breaking the beam is
latched so that the signal can be detected during the
next monitoring cycle performed by the controller.

In a further novel refinement an electronic fuse is
15 incorporated which provides protection for the interface
against the outputs being wired up incorrectly, or any
other cause of excessive current passing through the
device. This is illustrated in Fig 7 to which reference
is now directed.

20 The device is controlled by two microprocessors A and B.
When there is no signal generated from the device,
microprocessor A received 0 (zero) volts, so that
transistor T3 remains off and no current flows through
25 resistors R2 and R3. Because of this, transistor T2 does
not switch on and output C remains low.

When a voltage for example more than 2 volts is applied
to A, transistor T3 switched on. Thus current flows
30 through resistors R2 and R3, supplying current to
transistor T2 which switches on and allows current to
flow through resistor R4 and the Zener diode D1 so that
the output C goes high.

10

The sensor circuit comprises transistor T1 and the microprocessor B. In the normal current state, for example, the voltage across R4 due to the current flow is less than 0.6 volts, transistor T1 does not switch on, no
5 current flows through resistor R1 and the output to microprocessor B is low.

When excessive current is produced in the circuit for any reason, so that the voltage across resistor R4 is greater
10 than 0.6 volts, transistor T1 switches on, current flows through resistor R1 and the output to microprocessor B goes high.

This output is monitored by the microprocessor, which can
15 be programmed to operate immediately and reduce the output of microprocessor A to a low value, giving a fast response fuse. Alternatively the microprocessor B can be programmed to provide a delay to accommodate quick

current surges which are not critical.

20 This type of fuse can be used, for example, to give a time delay characteristic during start up when current surges in the component are to be expected but to switch to fast blow when the circuit is stabilised.

25 As an alternative to using microprocessors, a mono-stable or a set/re-set latch.

The present invention has been described and illustrated
30 using a laser diode as a light source from which the light beam 12 is created. However, other forms of electromagnetic radiation may be employed, and a light emitting diode or an incandescent light source may be used to create the beam 12 with the proviso that a

22-11-99 15:07 01454524901
22-NOV-1999 15:13 FROM RENISHAW PLC

P.13 R-186 Job-922
TO 901633814444 P.13

11

sufficiently high luminosity may be obtained from the
possibly divergent beam at the detecting unit 14.

1/4

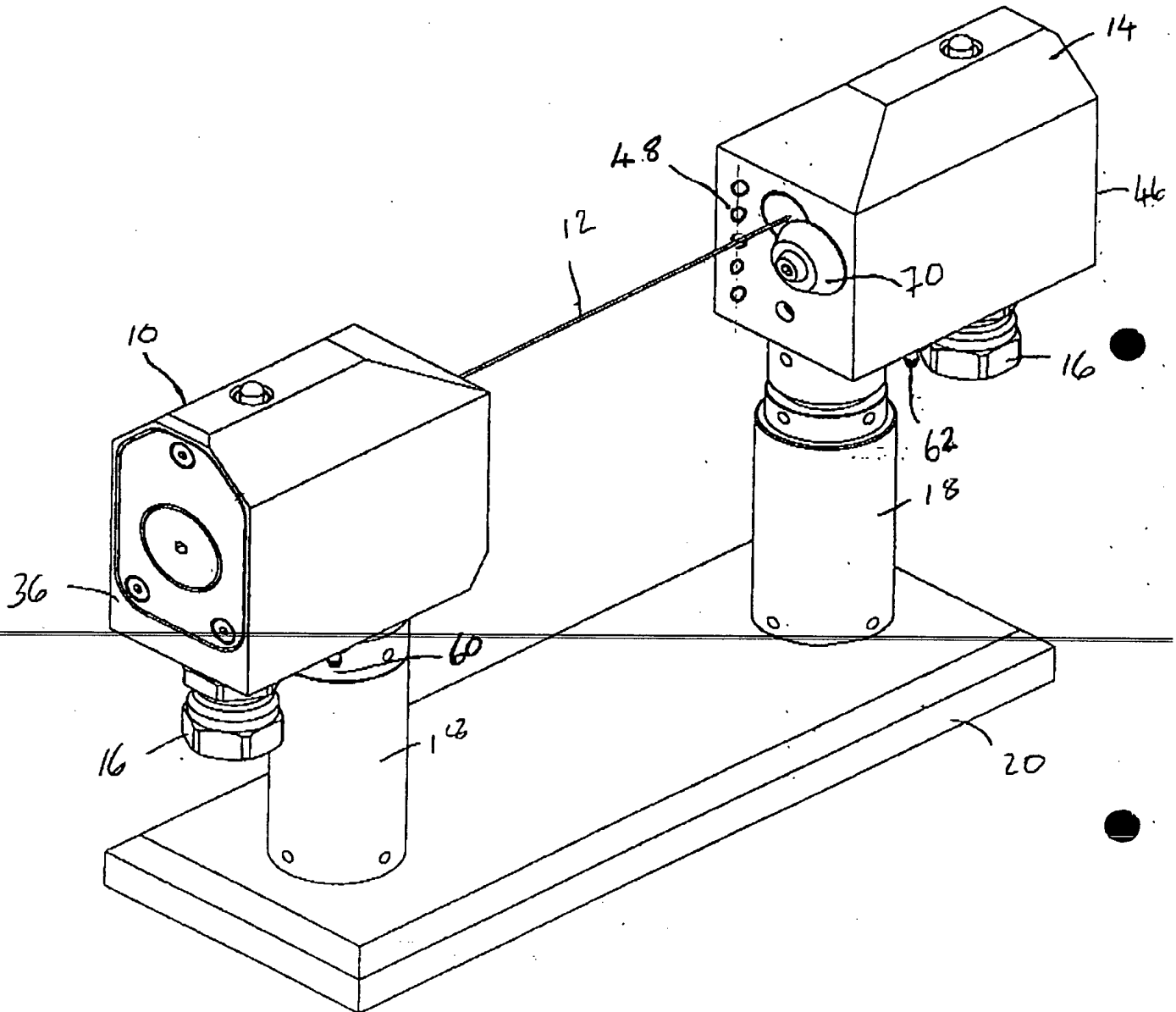


Fig. 1

2/4

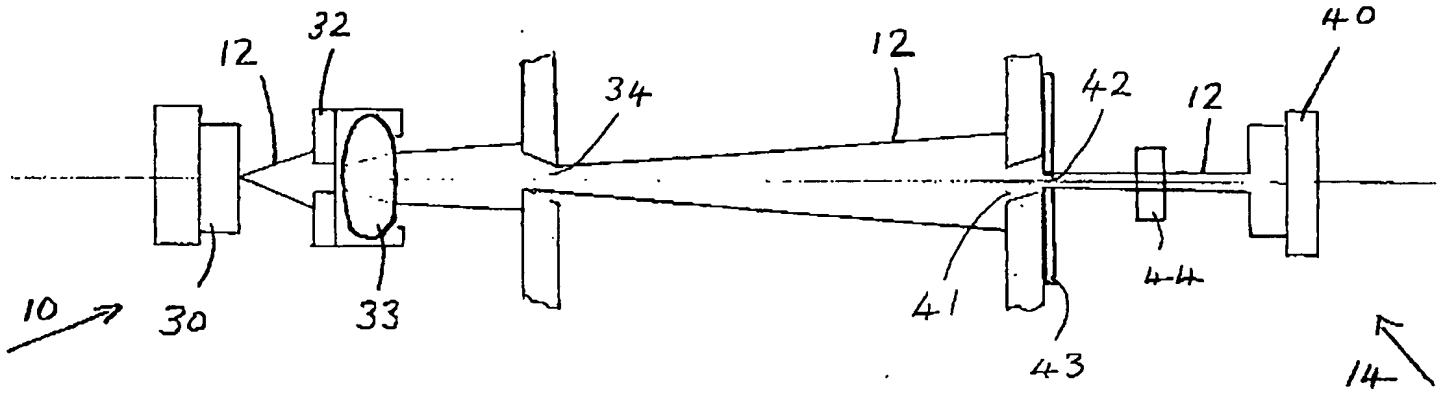


FIG 2

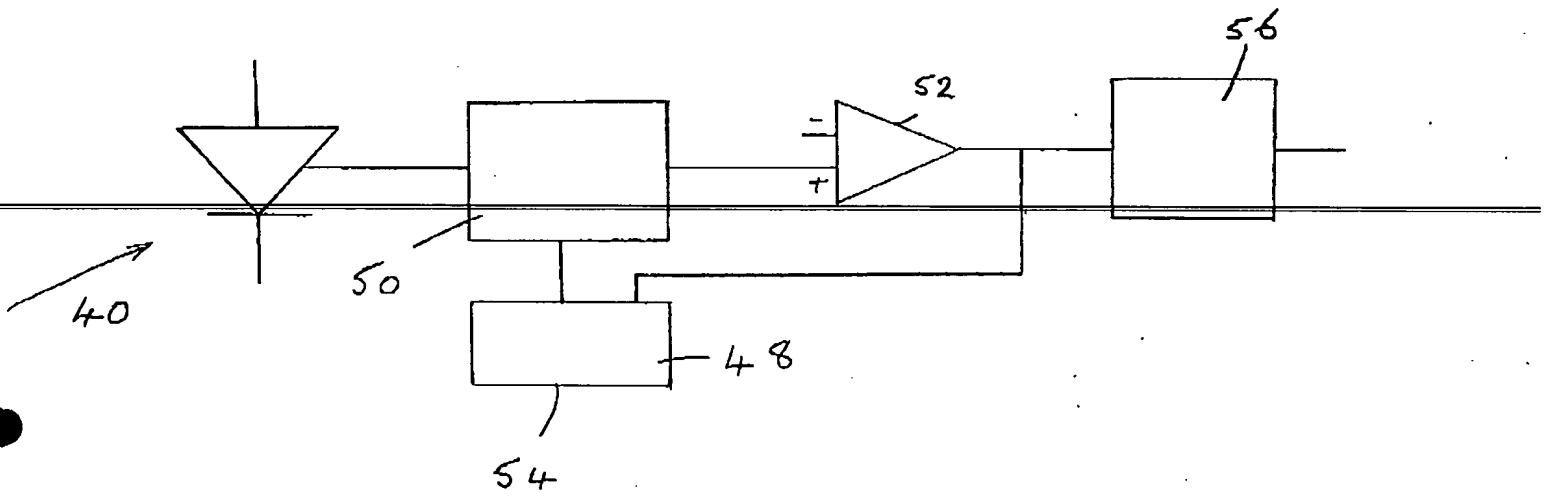


FIG 3.

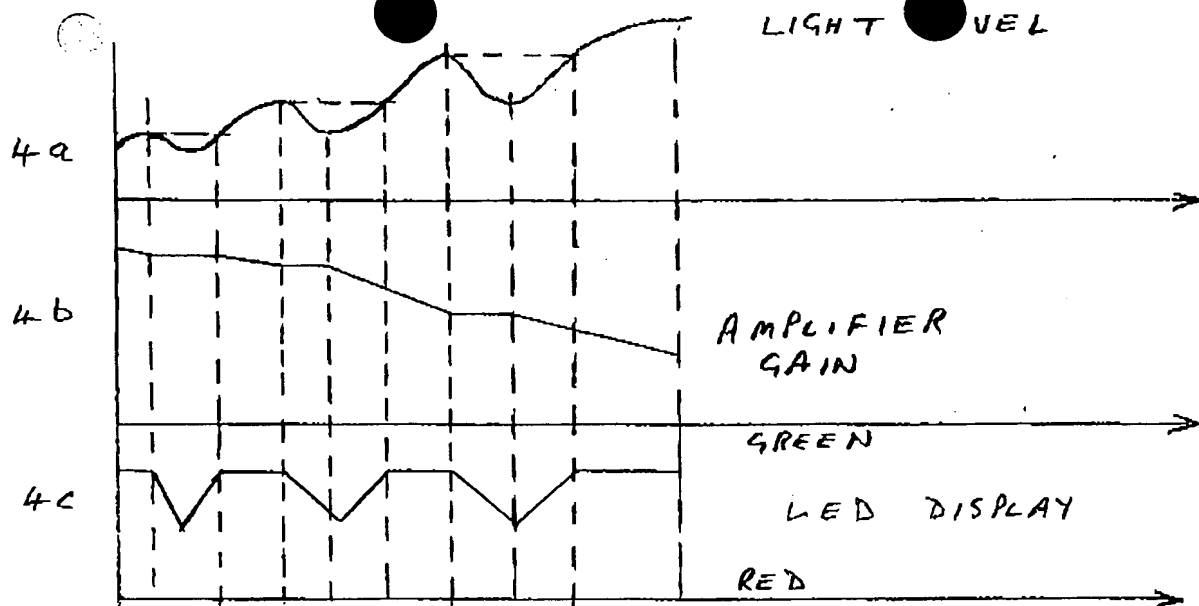


FIG 4

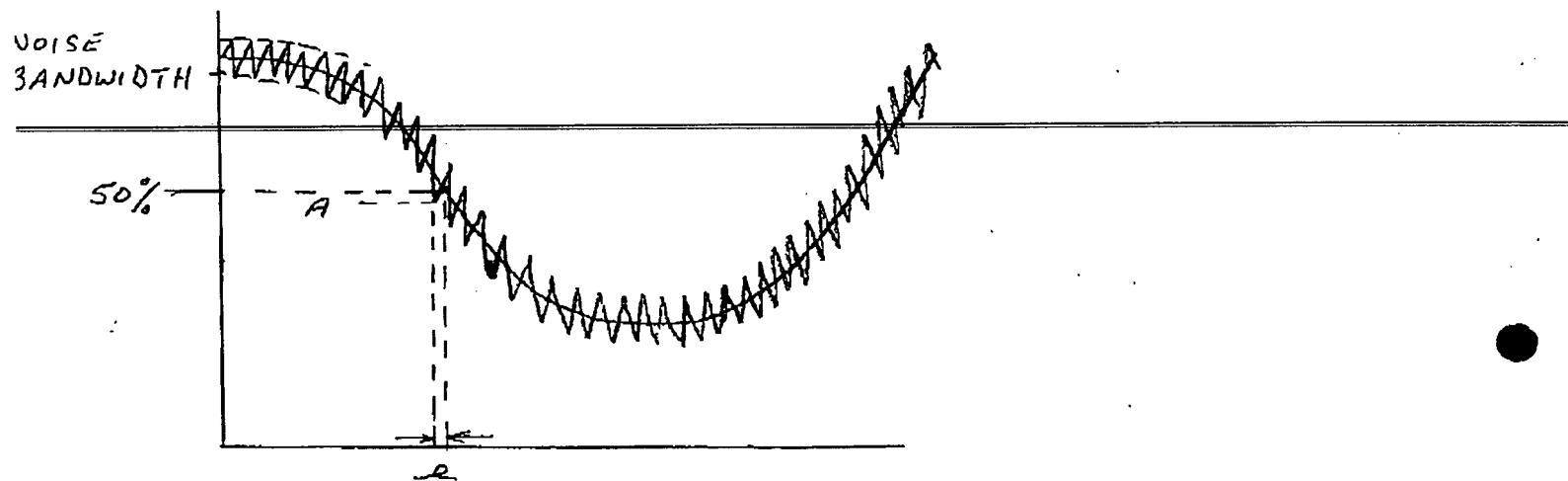


FIG 6

4/4

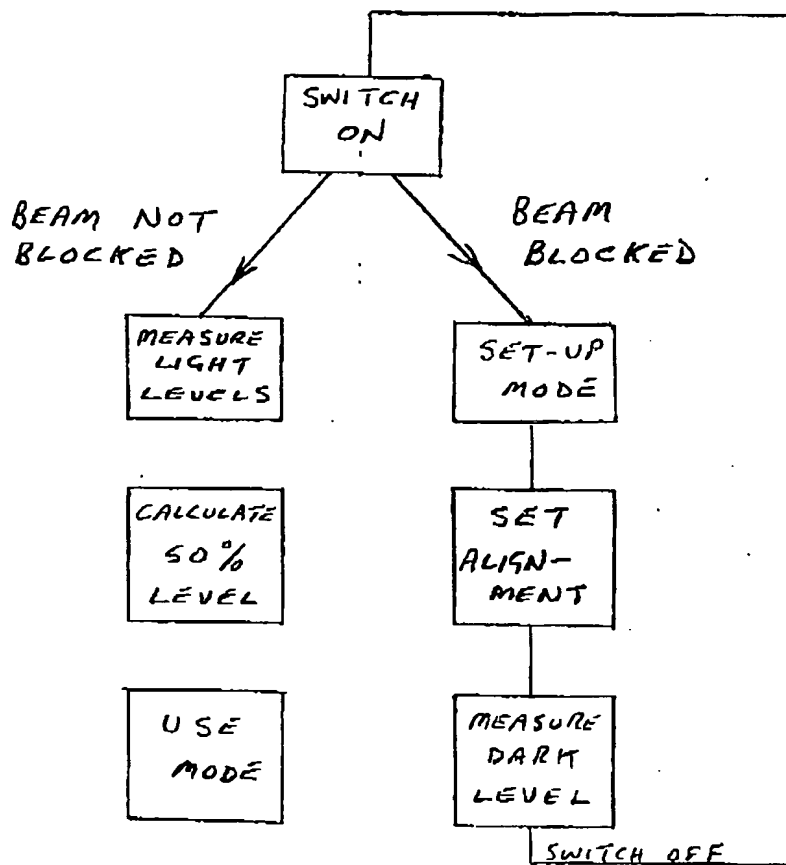


FIG 5

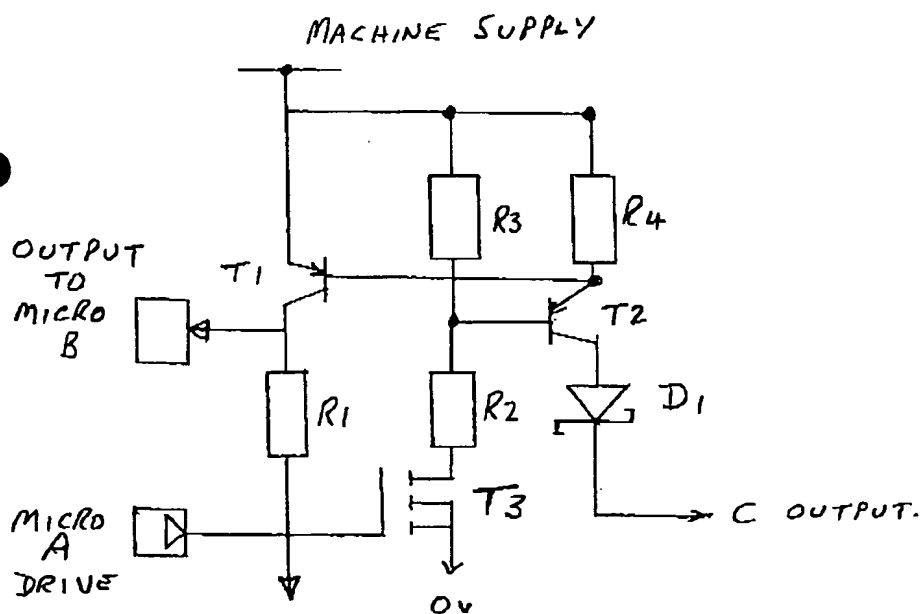


FIG 7

52

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☒ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

THIS PAGE BLANK (USPTO)